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Skills Scarcity and Export Intensity

Abstract

We describe a model of trade with input based product differentiation and non-proportional trade costs that is capable of predicting a positive correlation between firms' export intensity, the price of their exports, and the wages they pay to their workers. These correlations arise in the model solely from comparative input scarcity and independently of any productivity differentials: in equilibrium, firms that employ workers with comparatively scarcer skills, other things equal, export a larger proportion of their output, pay higher wages and charge higher prices.

JEL-Codes: F120, F160, E240.

Keywords: export intensity and wages, input based product differentiation.

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1 Introduction

The idea that firms are heterogeneous in terms of their total factor productivity (TFP) has proved very useful for explaining salient features in firm-level data. TFP differentials can account for the observed patterns of firm size, market share and export conduct. Studies that focus on product-level data find that the interaction of TFP and the scope for vertical differentiation can account for firms' product choices. In Kugler and Verhoogen (2012), firms endowed with higher TFP purchase higher-priced, higher-quality inputs and sell higher-quality outputs at higher prices; and Feenstra and Romalis (2014) show how endogenous quality choices can account for the observed patterns in export conduct.[1]

Building around this paradigm, the literature on heterogeneous firms (with few notable exceptions, discussed below) interprets the observed positive relationship between firms' export conduct and the wages they pay to their workers as being also driven by their given technology,[2] i.e. firms employ the labor inputs that are best suited to produce output of the quality that is best suited to their technology, with no major role played by the economy-wide supply of differentiated labor inputs. But a growing amount of evidence clearly points to firms' choices being limited by supply constraints. Producers consistently report skill shortages in their labor inputs.[3] This observation is also reflected in the findings of the empirical labor literature, which highlights the difficulties that firms face in filling vacant positions for more specialized jobs (Davis et al.,

[1]TFP differentials can also account for variation in further margins of choice. A shift in the (quality adjusted) marginal cost might have repercussion on the markup the firm charges, as in Melitz and Ottaviano (2008), and on the endogenous product mix of multi-product firms, as in Bernard et al. (2011), Eckel and Neary (2010), Mayer et al. (2014), among others. Helpman and Itskhoki (2010), Helpman et al. (2010), Felbermayr et al. (2011) and Gopinath et al. (2012) focus on the role of rent-sharing mechanisms; Egger et al. (2013), Amiti and Davis (2012), Davis and Harrigan (2011) present efficiency wage arguments. Positive assortative matching between high-productivity, export-intensive firms and high-skill workers is discussed in Yeaple (2005) and Sampson (2016).

[2]It has been widely documented that exporters are more profitable, sell higher-priced goods and pay higher wages than non-exporters do. Bernard et al. (1995), Roberts and Tybout (1997), Bernard and Jensen (1999), Bernard et al. (2003), Bernard and Jensen (2004), De Loecker (2011), Pavcnik (2002), Bernard et al. (2012) all document the exporter productivity premium. Baldwin and Harrigan (2011), Hallak and Sivadasan (2013), Hummels and Klenow (2005), Feenstra and Romalis (2014), Gervais (2015) find that exporters tend to charge higher prices.

[3]According to the McKinsey *The World at Work* report of 2012 employers in advanced economies are expected to face a shortage of sixteen to eighteen million college-educated workers by 2020, while in China this number will grow to twenty-three million; see `https://www.mckinsey.com/global-themes/employment-and-growth/the-world-at-work`. Jansen and Lanz (2013) document how the export competitiveness of small and medium sized enterprises is constrained by skill shortages.

2013). In relation to international trade, Labanca et al. (2014) find evidence that firms planning to export toward a certain destination poach workers from other exporters that are already present in that destination. The importance of worker-specific characteristics, beside firm-specific attributes, has also been documented by Irarrazabal et al. (2013), who show that roughly half of the exporter wage premium is explained by the prior employment history of workers.

This suggests that the relationship between firms' export conduct and their wages is driven not just by their technology but also by supply constraints. Firms must compete in the labor market to secure the skill types that are required to produce the products they sell; and so, economy-wide supply constraints must feed into firms' prices and their export conduct, and can be a contributing factor, alongside TFP heterogeneity, to the observed co-variation between wages, prices and export performance.

We formalize this argument in the context of a model of international trade with monopolistically competitive firms employing differentiated labor inputs that contribute to making their output differentiated from that of other firms. We focus on a stylized scenario where production requires a single category of differentiated labor – different types of workers of the same occupation – alongside an undifferentiated input. To best highlight how the co-variation between wages, prices and export conduct can be driven by labor supply alone, we deliberately choose to abstract from TFP heterogeneity.[4] We also do not need to model quality explicitly: under fairly general conditions, absent TFP heterogeneity, in our model vertical differentiation is observationally and analytically equivalent to horizontal differentiation in the presence of comparative input scarcity.

The prediction of a positive correlation between wages, prices and export conduct, as well as other salient patterns we observe in firm-level data, arise in the model from the combination of two main channels: (i) constraints in the aggregate supply of differentiated labor inputs; and (ii) non-iceberg trade costs, which translate into a positive relationship between output prices and export intensity – i.e. an "Alchian-Allen effect" (Alchian and Allen, 1972). Our framework also generates a rich set of predictions about the distribution of measured productivity (output per worker), on the distribution of wages, and the effect of a trade liberalization on wage inequality; all from a minimal theoretical toolkit.

[4]We later discuss how the unquestionably important channel through which TFP heterogeneity induces heterogeneous conduct could be embedded in our parsimonious setup.

To motivate our modeling exercise, we document a number of stylized facts in matched employer-employee and customs transactions data for French exporters.[5] The data contains detailed information on worker characteristics that makes it possible to differentiate the types of labor employed by each firm.[6] We first isolate the component of the wage that is explained by worker characteristics that are unrelated to the firm and to the sector of employment (as opposed to firm- or output-specific attributes); we find that the component of variation in wages that is explained by variation in the market wage is, on average, larger than that which can be attributed to firm characteristics. Second, although we observe a positive correlation between the wages paid by a firm and the prices it charges for its products – as the literature has documented – when we look for the same pattern across firms that employ workers with similar characteristics, such a conclusion is far from being a systematic regularity: only for a minority of worker types, about 12%, we observe a positive and significant correlation between their wage and the price that their employers charge for their products. The combination of these two stylized facts provides support to the conclusion that only a limited subset of worker types influence prices and sales in export markets; and that for those worker types, firms are, to a large extent, price takers in the labor market.

The model we present in Section 3 develops naturally from these premises. With input based product differentiation, comparative input scarcity is all that is needed to generate a positive relationship between wages and prices: the comparative scarcity of different skill varieties translates into higher prices for the goods produced using scarcer skills and higher wages for those skills. A comparatively lower incidence of transport cost on export prices for higher-priced goods can then explain the positive relationship between wages and export performance. This also means that international market integration raises the demand for comparatively scarcer, higher-wage skills, rel-

[5]The data covers the universe of French manufacturing firms. For each employer-employee match, we observe the gross hourly wage and many characteristics of the employee. Export transactions are at the product-firm-destination-year level. As a proxy for the firm export price we use a weighted average at the firm level of export unit values by product and country destination. A full description of the data sources and of how we use them is given in the Section A of the Appendix. We restrict our analysis to a four-year time window – 2010 to 2013 – which is short enough to mitigate concerns for the possible confounding effects of long-run phenomena – such as technological change, or structural changes in local labor markets.

[6]We are able to discriminate between the employment of *not qualified operators*, *qualified operators*, *technicians*, *experienced technicians* and other occupations. This level of observation is at least as detailed as what is typically assumed in studies on quality upgrading to discriminate between different technologies and quality standards.

ative to more abundant labor inputs, raising wage inequality.

Our study contributes to two lines of research: one seeking to explain the relationship between export performance and prices (e.g. Feenstra and Romalis, 2014, Kugler and Verhoogen, 2012, and Manova and Zhang, 2012); the other seeking to explain the relationship between export performance and wages (e.g. Helpman et al., 2010, Egger et al., 2013 and Helpman et al., 2017). Our model offers a parsimonious framework in which both research questions can be handled. While existing models focus on the role played by firm choices independently of input market constraints, our formalization sheds light on the role played by the economy-wide supply of skills as a determinant of firms' export conduct.

We also add to the large body of literature studying trade models based on relative factor proportions; recent contributions are Romalis (2004), Bernard et al. (2007), Bombardini et al. (2012), and Harrigan and Reshef (2015). Although our model builds on a classical factor-proportions argument, the presence of input based product differentiation and non-iceberg trade costs leads to a novel interpretation of the relationship between endowment differentials and the effect of trade on price, wage, and productivity in comparison with extensions that combine comparative input scarcity with output differentiation but do not link the latter to input differentiation: in the model, goods that are produced with comparatively scarcer skills are predicted to be exported comparatively more.[7] The interplay between factor proportions and non-iceberg costs in accounting for inter-sectoral trade differentials has previously been described by Matsuyama (2007), but has not before been applied to explain the systematic variation in export conduct across firms within sectors and the corresponding wage variation across firms within occupations.[8]

[7]In Bernard et al. (2007), firm heterogeneity in TFP introduces a Ricardian channel that reinforces the classical Heckscher-Ohlin mechanisms. In comparison, in our theory (which abstracts from TFP heterogeneity across firms and heterogeneity in factor intensity across sectors), international trade affects prices, wages and export performance because the relative demand for higher-priced goods, which are produced with skills that are scarcer in the domestic economy, is greater in export markets than in the domestic market.

[8]The role of specific labor types for firm performances has received attention in two other recent contributions, which also look at evidence for French exporters. Caliendo et al. (2015) show that firms willing to expand pay more for certain types of occupations (higher in the organizational hierarchy, in their terminology), while they pay less for the others. Harrigan et al. (2016) investigate the rise of wage polarization in the French labor market, and they conclude that polarization is driven by the changes in the wages of certain specific worker types (those with technology-related occupations, in their terminology). Our interpretation is consistent with both findings.

The rest of the paper is structured as follows. Section 2 presents evidence for French exporters that motivates our modeling choices. Section 3 outlines the model, characterizes autarky and open-economy equilibria, derives the main predictions about the relationship between export intensity, prices and wages. Section 4 concludes.

2 Evidence on wages, prices and export conduct

We begin by documenting patterns in firm-level data for French exporters that support the idea that firms' export prices reflect variation in market wages, but that they do so only for a subset of worker types (which can therefore be considered as being related to the extent of product differentiation in export markets). Evidence of input differentiation between exporting and non-exporting firms, as well as across exporters, has been found in other contexts: the aforementioned study for Norway by Irarrazabal et al. (2013) shows that firm characteristics can account for only one-half of the exporter wage premium, with the remaining half coming from workers' characteristics that are exogenous to the firm; and Manova and Zhang (2012) document how the export performance of Chinese firms is related to the characteristics of imported inputs.

The dataset we employ collects information on all contracts between French firms and their employees, which is merged with information on firms' balance sheets and their export transactions, if they are exporting. The information is at yearly frequency and covers a four-year time window from 2010 to 2013, and is particularly rich in the description of occupations. We exploit this advantage to classify employer-employee matches by a dense grid of narrowly defined occupations (*worker types*) and by several levels of qualification within each occupation (*skill types*) within that occupation.[9] For every contract between a French employer and an employee we observe a firm's identifier, f, the worker's type, r, her skill type, s, and the year, t. In addition, we observe the sector of main activity of the firm (from 231 codes at NACE 4-digit level), and the region where the place of employment is located (from twenty-five, administrative re-

[9] A worker type is defined as a distinct combination of: demographic characteristics (age class and gender), type of contract, province of residence, province of the working place location, and occupational category. The last dimension is quite rich: 6 broad categories indexed with 1-digit codes are hierarchically organized into 18 groups at 2-digit codes, and 408 groups at 4-digits codes; where more digits are consistent with the interpretation of a further qualification within the previous broader category. We discriminate by worker type at 2nd digit (3,448 distinct cells). We discriminate by skill type at the 4th digit level (on average 3.5 levels per worker type).

gions of France). For each firm/year pair, we compute a within-firm log average, w_{rsft}, of gross wages for all contracts that appear with the same worker type and the same skill type, arriving at 262,450 distinct observations across 11,989 distinct firms for 752 distinct worker types, over four years.

Across-firm wage variation and market wages

To what extent do the wages that firms pay to their workers reflect the labor market price for the particular skills of those workers, as opposed to a firm-specific premium?

To examine this question, we proceed as follows. For every combination of a worker/skill type pair observed in a given firm that operates in a certain sector in a given year (for which we have computed a firm-level log average wage, w_{rsft}, as previously described), we compute a corresponding weighted average hourly wage across all firms that employ the same worker/skill type pair in the same region and in the same year but operate in a different sector, where the weights are hours worked. The resulting measure, w_{rsft}^{MKT}, does not draw on information that is specific to the firm in question, but only on the market price for the particular worker/skill type pair that the firm employs.

We then carry out a wage decomposition exercise, in the spirit of Abowd et al. (1999) and of more recent contributions (such as Macis and Schivardi, 2016, Helpman et al., 2017, and Card et al., 2018); but, unlike these studies, we are interested in decomposing the variation in *average* wage at the level of worker/skill type, rather wage variation at the individual worker level.[10]

The results of this decomposition exercise are shown in Table 1. In the upper panel, we isolate the firm-specific wage premium by means of a firm-year dummy (d_{ft}), and occupational differentials by including worker-type dummies (d_r). Firm characteristics explain 12.2% of the unconditional variation in the average wage by worker/skill type (w_{rsft}),[11] with the remaining fraction of the total explained variation (73.8%) being attributable to variation across occupations. These findings are in line with those of

[10]In those studies, the dependent variable is the log hourly wage of a worker in a year. In our exercise, the dependent variable is the average of the log hourly wage among individuals with the same worker type and skill, employed at the same firm in the same year.

[11]This contribution is measured by $\mathrm{Var}(\hat{\beta}^2_{ft} d_{ft}) + 2\,\mathrm{Cov}(\hat{\beta}^2_y d_y, \hat{\beta}^2_{ft} d_{ft})$.

Table 1: Wage decomposition: firm characteristics vs. market wages

Specification	Market Wage	Firm	Worker Type	Total Explained
	Share of wage variation by source			
$w_{rsft} = \beta_0^1 + \beta_r^1 d_r + \beta_{ft}^1 d_{ft} + \varepsilon_{rsft}$	—	12.2%	61.6%	73.8%
$w_{rsft} = \beta_0^2 + \beta_w^2 w_{rsft}^{MKT} + \beta_r^2 d_r + \beta_{ft}^2 d_{ft} + \varepsilon_{rsft}$	13.8%	12.1%	48.1%	74.1%

Abowd et al. (1999) and other subsequent studies (summarized by Card et al., 2018).[12]

The lower panel of Table 1 also includes our measure for market-based wages (w_{rsft}^{MKT}), which, by construction, does not contain any information on factor-neutral, firm-specific attributes. The total explained variation and the contribution of firm characteristics to overall wage variation both remain roughly unchanged; but a sizeable portion (13.8%) of the variation previously explained by occupational variation is now accounted for by within-occupation variation in the market wage for different skill types.[13] This component of wage variation is fully attributable to market conditions that are exogenous to the firm, and is not quantitatively less important than the firm/year contribution (12.1%).

Price-to-wage correlation

A number of empirical studies have documented how firms that charge higher prices (and earn greater revenue in export markets) are also the ones that pay higher wages. Some of this effect is channeled through the component of the wage variation that is explained by firm-specific attributes. Nevertheless, we have shown evidence that firms'

[12]Typically in these studies the control for occupation is much broader than the very narrow classification by worker type, that we apply. Hence, ceteris paribus, in our exercise, the variation explained by the battery of occupation dummies tends to be larger. Even discounting for this motive, the conclusion on the limited importance of firm effects is remarkably consistent. Card et al. (2018) document a range of 15%-25% for the contribution of firm fixed effects, surprisingly robust among countries with different institutions and technological development. Even when assortative matching is taken into account, authors conclude that less than 40% of the variation in average hourly wage is attributable to a firm premium or to the sorting of higher ability workers to more productive firms.

[13]This is measured by $\text{Var}(w_{rsft}^{MKT}) + 2\,\text{Cov}(\hat{\beta}_w^2 w_{rsft}^{MKT}, \hat{\beta}_y^2 d_y)$.

wage bills must also reflect market wages. Given this, how much of the correlation between export price and wages is channeled through the variation in the market price across different skill types within occupations?

To address this question, we focus on the covariation of prices and wages, for any given worker type, across exporters belonging to the same sector of activity and operating in the same geographical region at a certain point in time; i.e. *labor market segments* defined by a combination of worker type × sector of main activity of the employer × region × year. All firms that belong to the same labor market segment employ the same worker type, locate production in the same region, compete in the same sector, in the same year. Focusing on exporting firms only, for each we construct an export price measure, p_{ft}, that can be compared with that of other French firms that export the same product, to the same country destination, in the same year.[14]

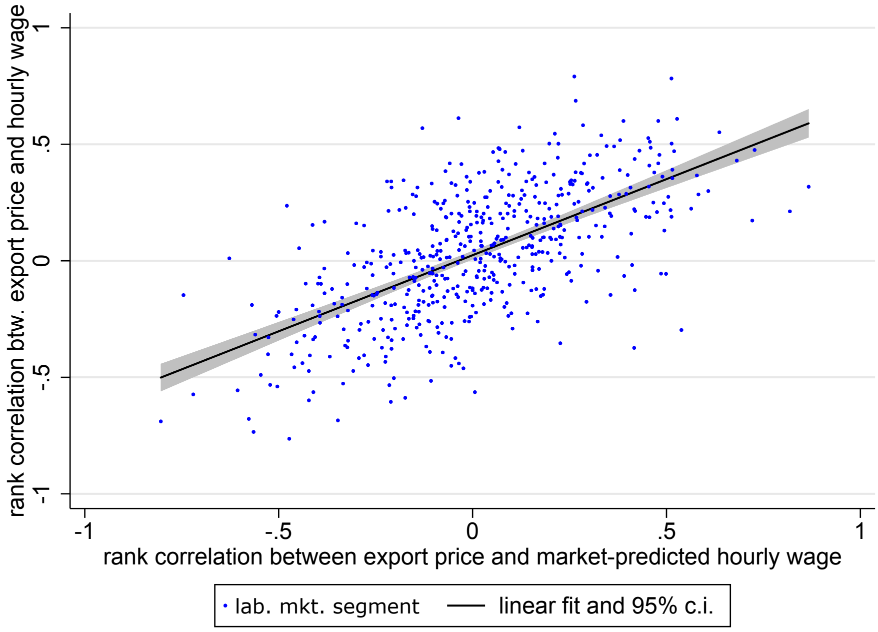
We then compute two separate measures of rank correlation between export price, p_{ft}, and firms' average wages within each labor market segment, one measure using the firm-level average, w_{rsft}, the other using the market-level average, w^{MKT}_{rsft}. The only source of wage variation involved in this calculation is across firms and across skill types.[15] In particular, among firms within a labor market segment that employ the same skill type there is no variation in the market-based wage measure. It follows that the rank correlation between output prices and firm-level wages across firms involves two separate components: variation in wages attributable to firm characteristics and variation in the skill types employed by different firms. In contrasts, the correlation between output prices and market-based wages only draws on the second component – i.e. it only reflects the extent to which firms that charge different prices employ, for worker types that are present at the firm, different skill types that command different market wages.

Figure 1 is a scatterplot of the price-to-wage rank correlation of prices and actual wages, $\text{corr}(p_{ft}, w_{rsft})$, on the vertical axis, against the price-to-wage rank correlation of prices and market-based wages, $\text{corr}(p_{ft}, w^{MKT}_{rsft})$, on the horizontal axis, where each dot

[14]The details on the sources, on the data cleaning and on the construction of export prices starting from product-firm-country destination unit values are discussed in Section A of the appendix.

[15]To avoid that our results are driven by rare employer-employee matches we take into account only labor market segments populated by at least ten firms. Moreover, the grid of worker types is so dense that we do not observe the same firm in the same labor market segment more than once; this means that a firm in a labor market segment employs only one skill of a worker type. Of course different firms, within the same labor market segment, might employ a different skill of the same worker type.

Figure 1: Export prices-to-wages rank correlation:
prices-to-actual wages vs. prices-to-market based wages



refers to a given labor market segment (as defined above). There is a positive and significantly association between the two correlation measures. This means that there is a substantial component of the observed price-to-wage correlation that can be rationalized by the co-variation of output prices and market prices for labor inputs and that is independent of firm characteristics.

Figure 1 reveals another pattern: only for a minority of worker types do we observe a positive correlation between their wage and the price that their employers charge in export markets. To see this, note that the vertical coordinate of each point measures the price-to-wage correlation (actual wages) across firms that employ the same worker type in the same region and compete in the same sector at the same time (a labor market segment). So, if firms charging higher prices paid their employees more independently of their type, we should see most points lying above the zero line; but this is not the case. Instead, we observe a positive and significant correlation between wages and prices in only about 12% of the labor market segments. This finding does not conflict with findings elsewhere in the literature – the evidence does say that there is a positive price-to-wage correlation for French exporters, *on average*. However, when we look for evidence of a relationship between wages and prices separately by worker type, the conclusion that prices and wages correlate positively across firms does not apply in a systematic way to all worker types, nor to a majority of worker types.[16] For worker types for which we find no correlation, wage variation across workers of the same worker type but different skill types can be interpreted as arising from productivity differentials that are orthogonal to output characteristics and thus do not affect firms' costs and prices.[17] In contrast, for those worker types for which we see a positive correlation, differentials in the mix of skill types employed across firms are associated with products that command different prices (and that must therefore be differentiated from one another in some way).

Export prices and export intensity

The empirical evidence points to a channel linking intensive-margin exporter wage premia to export prices, i.e. exporters that charge higher prices and pay higher wages derive a comparatively larger proportion of their total revenues from their exports.[18] The final link in this channel is the well-documented positive relationship between export prices and export intensity: a number of empirical studies have shown that exporters that charge higher prices earn greater revenues in each export destination (Alchian and Allen, 1983; Manova and Zhang, 2012) and that transport costs are less than unit elastic with respect to price (Hummels and Skiba, 2004).

An analogous pattern is found for French exporters. Table 2 presents results of regressions of log export intensity on price.[19] The first column reports results for the entire sample; in the second column we restrict the analysis to firms that export their main product to destination countries with a land border and common currency with France (i.e. Belgium, Italy, Germany, Luxembourg, Spain); in the last column we only include

[16]Moreover, it is simply not the case that high-wage occupations are also the ones for which we observe higher price-to-wage correlation: if we look at which labor market segments exhibit greater and lower price-to-wage correlation, we can see no clear sorting by wage level or broad occupational category.

[17]Productivity differentials across inputs that simply translate into different productivity-adjusted quantities of a homogeneous input and are accordingly reflected in the market prices of those inputs have no consequences for cost and price.

[18]Descriptive evidence on wage premia for French exporters is presented in Appendix C.

[19]We include sector-destination-year dummies and firm dummies, impying that we only exploit within-firm longitudinal variation. As previously described, the transactional data from French customs makes it possible to carry out price comparisons at the 8-digit product level. If a firm exports more than one product and/or to more than one destination, we keep the price of the product-destination pair in which the firm has the highest export value in the year.

Table 2: Export prices and export intensity

ln *Export Intensity*	All destinations	Bordering destinations	Non-bordering destinations
ln *Export Price*	0.142***	0.112***	0.153***
	(0.019)	(0.033)	(0.023)
No. Clusters (NC6 product-destination-year)	3,884	946	2,938
R^2	0.311	0.257	0.278
No. Obs.	10,882	2,584	8,298

NOTE: All specifications include firm and year fixed effects. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors (reported in parentheses) are clustered at product-destination-year level.

firms that export their main product in the remaining destinations. The elasticity of export intensity to price (first column) is 14.2% and is statistically highly significant. Comparing the second and third columns reveals that the elasticity of export intensity to price increases with distance, going from roughly 11.2% for bordering destinations to 15.3% for non-bordering destinations, a further indication that non-proportional trade costs may play a key role in driving the relationship between prices and export intensity.

The fact that high-price firms earn comparatively greater revenues in export markets, combined with the finding that the correlation between firm prices and wages reflects variation in market wages and the non-systematic way in which the correlation of wages and prices varies across different worker types, points to an interpretation according to which firms are supply constrained with respect to the use of certain types of labor inputs that differentiate their products from those of their competitors, and that variation in the price of the goods they produce – and thus variation in the proportion of their output that is exported – reflects, to some extent at least, variation in the supply of those inputs.[20] In this interpretation, firms that produce goods that use comparatively scarcer skill types pay them more and export more. We formalize this idea below.

[20] Appendix C provides additional evidence on exporter wage premia. This is in line with what the literature has documented, both at the extensive and at the intensive margin.

3 Trade with factor-based product differentiation

In this section we describe a model of international trade with input based product differentiation that directly links input prices to output prices. The model relies solely on the toolkits of neoclassical economics, augmented by Chamberlinian monopolistic competition, and employs a minimal set of ingredients: (i) different types of a given labor input category confer different characteristics to the goods that are produced with them (we further elaborate on this point below); (ii) different types of a given labor input category are differentially scarce; (iii) product varieties that are made by different firms using similar labor input types are viewed by users as being closer substitutes than product varieties that are made with different labor input types; (iv) the labor inputs used in the production of trade services are comparatively less differentiated than those used to produce the goods that are traded. We show that such a theory is able to produce a rich set of predictions on observables (values, prices and quantities) that match observed empirical patterns; specifically, it naturally predicts a positive correlation between export intensity and wages.

Our modeling exercise abstracts from factor-neutral productivity differentials – not because we wish to argue that they are not important, but to underscore that the relationships predicted by the model do not require productivity differentials to be present. As we later discuss, productivity differentials can be readily incorporated into our modeling framework.

We first discuss the idea of input based product differentiation and show how, when prices and quantities are inversely related (as we observe them to be in the data), a model of horizontal differentiation provides a fully sufficient representation of substitution possibilities whether or not products are also vertically differentiated. We then describe the model's basic structure, and proceed to derive predictions about autarky equilibria and open-economy equilibria.

3.1 Input based product differentiation

The model that is presented in Section 3.2 is based on the idea of input based product differentiation, i.e. the notion that different varieties of inputs of the same input category incorporate (unobservable) differences that make the product varieties produced with them differentiated in terms of their characteristics. As we explain below, provided that certain conditions are met, the link between input differentiation and product differentiation can be modeled without making any formal distinction between vertical and horizontal differentiation.

Consider a continuum of varieties of a certain good, each identified by an index $s \in [\underline{s}, \bar{s}] \equiv S$. Production uses a single type of a given input category, with different input types conferring different characteristics to the good that is produced with them – for example, spoons are made using a solid substance as an input (an input category), which can be plastic, metal or wood (a specific input type within the "solid substance" input category). Accordingly, buyers regard products made with different input types as being differentiated varieties of the same product – not because they directly care about the inputs, but only because they care about the characteristics that are embedded in the product (Lancaster, 1966).

Modeling differentiation across varieties as arising from a CES representation of preferences for horizontally differentiated varieties,

$$\int_{\underline{s}}^{\bar{s}} x(s)^{(1-\sigma)/\sigma} \, ds, \tag{1}$$

where $\sigma > 1$ and where $x(s)$ is quantity of variety s, gives inverse demand

$$p(s) = \varphi \, x(s)^{-1/\sigma}, \tag{2}$$

where φ is a constant. Let $L(s)$ be the market supply of the input variety required to produce output variety s, with $L(s)$ being continuous in s. Assuming a unit input requirement of unity for each variety (and abstracting for the time being from market structure and assuming zero markups), market clearing requires $x(s) = L(s)$, and so

$$p(s) = \varphi \, L(s)^{-1/\sigma}. \tag{3}$$

If $L'(s) < 0$, (3) implies $p'(s) > 0$, i.e. product varieties that embed scarcer input varieties have a higher price. If instead $L'(s) = 0$, prices are uniform across varieties. To continue with the spoons example, spoons made of wood, spoons made of plastic and spoons made of metal are horizontally differentiated, and might command the same price if the materials used to produce them were equally abundant; but input supply differentials can still give rise to price differentials.[21]

The above conclusions can be extended to environments where products are also vertically differentiated. Consider preferences represented by

$$\int_{\underline{s}}^{\overline{s}} \big(\omega(s)x(s)\big)^{(\sigma_V-1)/\sigma_V}\, ds, \tag{4}$$

where $\omega(s)$ is quality, $\omega(s)x(s)$ is quality adjusted quantity, and where $\sigma_V > 1$. Inverse demand can be written as

$$p(s) = \varphi\, \omega(s)\big(\omega(s)x(s)\big)^{-1/\sigma_V}. \tag{5}$$

In this formulation there is a vertical-differentiation element to substitution margins. Going back to the spoons example, the consumer views metal spoons as being of higher quality than wooden spoons, and wooden spoons as being of higher quality than plastic spoons. Suppose next that endowments are such that $\omega(s) = L(s)^{\eta}$, where $\eta < 0$, and that, as before, $L(s)$ is decreasing in s, i.e. scarcer inputs produce varieties that are of higher quality (and of which we observe fewer being produced). Then, by market clearing, (5) gives

$$p(s) = \varphi\, L(s)^{((\sigma_V-1)\eta-1)/\sigma_V}. \tag{6}$$

If there are no quality differentials (i.e. $\eta = 0$), and the elasticity of substitution is σ_H,

[21]This can be viewed as a limiting case of a specification where, for variety s, unit cost (expressed in logs) is

$$\ln c(s) = a \ln w(s) + \frac{1-a}{\overline{s}-\underline{s}} \int_{\underline{s}}^{\overline{s}} \ln w(z)\, dz, \qquad 0 \le a \le 1,$$

a specification consistent with the idea that firms are heterogeneous in terms of factor content, as in Harrigan and Reshef (2015); unlike in their study, however, in our model heterogeneity in factor inputs is the only feature that is required to generate a correlation between firms' factor content and their export behaviour. In Harrigan and Reshef's model, the relationship between firms' exporting behaviour and the wages they pay arises because of an assumed correlation between factor-neutral productivity and factor content. A more general way of modeling input based product differentiation would be by explicitly adopting a characteristics-based representation (Lancaster, 1966). Assuming a continuum of characteristics $\kappa \in [\underline{\kappa}, \overline{\kappa}]$, if each unit of good produced with skill variety s contributes a profile of characteristics $h(s,\kappa)$, then a consumption profile $x(s)$, $s \in [\underline{s}, \overline{s}]$ yields an aggregate profile of characteristics $H = \int_{\underline{s}}^{\overline{s}} h(s,\kappa)\, x(s)\, ds$. Convex preferences over aggregate profiles of characteristics, H, would then translate into product differentiation in demand.

the expression that corresponds to (6) is

$$p(s) = \varphi\, L(s)^{-1/\sigma_H}. \tag{7}$$

If

$$\sigma_H = \frac{\sigma_V}{1-(\sigma_V-1)\eta} < \sigma_V, \tag{8}$$

(5) and (6) will be exactly equivalent – in terms of observables, predicted responses, predicted welfare effects, and, specifically, predicted effects of changes in the distribution of $L(s)$ on prices, welfare and allocation choices. In other words, substitution between vertically differentiated varieties can be modeled in terms of a formulation with horizontal product differentiation that incorporates an adjusted substitution elasticity.[22]

Observational equivalence requires $\omega(s)$ to be decreasing in $L(s)$ and , i.e. $\eta < 0$, additionally to $L'(s) < 0$: if $L(s)$ and $\omega(s)$ were not inversely related, we would see higher-priced goods being sold in larger quantities – a pattern that is inconsistent with pure horizontal differentiation and that can only be ascribed to vertical differentiation. But in the case of French exporters we see a negative relationship between a variety's price and the quantity of that variety that is produced and sold,[23] which can arise both from products being vertically differentiated in consumers' preferences and from a combination of horizontal differentiation and differential supply constraints.

Thus, a model of horizontal differentiation with comparative scarcity provides a sufficient representation of demand responses for a class of models where prices and quantities are inversely related, and price differentials can be equivalently interpreted as reflecting scarcity differentials or quality differentials (or both). In what follows, we apply these ideas to develop a monopolistically competitive model of production and trade with differentiated varieties that are defined in terms of the type of workers used to produce them. In turn, if product differentiation in the model is based on the type of inputs (including labor inputs) employed in the production of different varieties in the

[22]Equivalence in the CES case requires the inverse relationship between $L(s)$ and $\omega(s)$ to exhibit constant elasticity. It is easy to show that, using a fully flexible representation of horizontal differentiation, any schedule $\omega(s)$ such that $\omega'(s) < 0$, together with quantity and price schedules $L(s)$ and $p(s)$ s.t. $L'(s) < 0$ and $p'(s) > 0$, can be accommodated to give equivalence.

[23]The distribution of firms' revenues is positively skewed, and the elasticity of revenue to price across individual firms is, on average, less than unity.

way we have described, price differentials across products can result directly from the comparative scarcity of those differentiating inputs.

3.2 Model setup

Endowments

There are m countries. In each country $i \in \{1, \ldots, m\} \equiv M$, individuals are endowed with two types of labor: undifferentiated labor and a single category of differentiated labor (heterogeneous workers of a single occupational category), with differentiated varieties of the latter (*skill varieties*) being indexed by $s \in [\underline{s}, \bar{s}] \equiv S$.[24]

Two types of goods are produced and consumed in the economy: an undifferentiated good, which is produced using only undifferentiated labor as an input at a constant marginal resource cost of unity, and differentiated goods of a single good category that are produced using both differentiated and undifferentiated labor inputs.

The supply of undifferentiated labor in the economy is fixed at $Y_i > 0$; the supply of skill variety s of the differentiated labor category is equal to $L_i(s) > 0$. Without loss of generality, we let input types be ordered such that $s'' > s' \;\Leftrightarrow\; L_i(s'') < L_i(s')$. For convenience, we assume that $L_i(s)$ is a differentiable function and is decreasing, i.e. $L_i'(s) < 0$.

Preferences and product varieties

Consumers have identical, quasi-linear preferences over differentiated and non-differentiated goods, represented by the utility function

$$U_i = Y_i^C + \frac{\zeta}{1+\zeta} Z_i^{\frac{1+\zeta}{\zeta}} , \tag{9}$$

where Y_i^C is consumption of undifferentiated goods in country i, Z_i is composite consumption of differentiated goods in country i, and $\zeta < -1$ is the price elasticity of demand for differentiated goods.

[24]As discussed above, we do not necessarily need to think of higher-s skill varieties as being "higher" skill types, although an interpretation in terms of vertical differentiation is possible – and, as we have shown, gives rise to an equivalent formulation and identical predictions.

Each skill variety, s, is associated with one and only one type, s, of differentiated goods. The composite consumption of differentiated goods consists of a constant-elasticity-of-substitution (CES) preference aggregation of good types:

$$Z_i = \left(\int_{\underline{s}}^{\overline{s}} X_i(s)^{\frac{\sigma-1}{\sigma}} ds \right)^{\frac{\sigma}{\sigma-1}} , \tag{10}$$

where $X_i(s)$ is the composite consumption of goods of type s in country i, and $\sigma > 1$ is the elasticity of substitution across goods of different types.[25]

In every country, i, for each good (and skill) variety, there are multiple firms each producing a firm-differentiated variety j of the given good type s, with the measure, $N_i(s)$, of firms producing differentiated varieties of good type s being large for each good type. The market populated by all varieties $j \in \bigcup_{i \in M} [0, N_i(s)]$ of a given good type s is characterized by a monopolistically competitive structure.[26]

The consumption of differentiated varieties of the same good type enters the composite consumption aggregate, $X_i(s)$, of good type s in country i through a CES preferences aggregation:

$$X_i(s) = \left(\sum_{h \in M} \int_0^{N_h(s)} x_{ih}(j,s)^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}} , \tag{11}$$

where $x_{ih}(j,s)$ is consumption of variety j of type s produced in country h by consumers in i, and η is the elasticity of substitution across different varieties of good type s.[27]

We assume $\eta > \sigma$, i.e. varieties of the same good type (produced by different firms with the same skill variety) are closer substitutes with each other than varieties of different good types (produced with different skill varieties). As will be shown later, a consequence of our model's structure is that varieties of the same good type, s, are sold at the same price in equilibrium, whereas varieties of different good types have different prices; and so $\eta > \sigma$ implies that varieties sold at the same price point are closer

[25]This representation involves horizontal differentiation; but as shown earlier, it can also subsume vertical differentiation.

[26]$N_i(s)$ is determined endogenously under conditions of free entry and exit, as discussed below.

[27]This structure effectively amounts to a factor-proportions model with monopolistic competition in which sectoral boundaries are narrower than industry boundaries, i.e. where a "sector" corresponds to a market segment within an industry.

substitutes for each other than varieties that are sold at different price points. This is consistent with findings described in the empirical literature on consumer choice that allows for differential substitution patterns within and across market segments (e.g. Grigolon and Verboven, 2014).

Technology and markets

A firm producing a variety, j, of good type s in country i employs $l_i(j,s)$ units of differentiated labor and $y_i(j,s)$ units of undifferentiated labor according to a Cobb-Douglas technology:

$$q_i(j,s) = \varphi \, l_i(j,s)^{\lambda} \, y_i(j,s)^{1-\lambda} \,, \tag{12}$$

where $q_i(j,s)$ is output, $\lambda \in (0,1)$ is the share of labor in total production costs, and $\varphi \equiv \lambda^{-\lambda}(1-\lambda)^{-(1-\lambda)}$.

In addition to variable costs, every active firm incurs a fixed production cost. This consists of $f > 0$ units of a composite input, produced with a technology analogous to (12), but with a share of firm's labor inputs $\alpha \in [0,1]$.

Firms sell the variety they produce both in the domestic market and in foreign markets. Markets are segmented internationally. Skill varieties are fully observable. Since only workers endowed with skill s can be used to produce goods of type s, equilibrium wages will be skill-variety specific. Labor markets are frictionless and competitive, which implies price taking behavior by firms with respect to wages and full employment.[28]

Trade costs

In order to sell differentiated goods in export markets, firms must combine the differentiated good they produce with export services, such as market-specific marketing, establishing and handling distribution channels, complying with export-market specific laws, regulations, and standards. We assume that the exported goods and export services are perfect complements. One unit of exported output from country i to coun-

[28]Since firms are all ex-ante identical and have access to the same technology, they all break even in a monopolistically competitive equilibrium. This means that the sorting of firms across skill/good types is irrelevant in this context (which would not be the case if firms were heterogeneous with respect to their technologies, e.g. if they had different productivity levels or different fixed cost levels).

try h requires b_{ih} units of export services, where the parameter b_{ih} captures the level of trade barriers faced by a firm producing in country i when exporting to country h, such that $b_{ii} = 0$ but $b_{ih} > 0$ for every $h \neq i$.

The technology used to produce export services is analogous to (12), but employs the firm's output according to a share $\xi < 1$,

$$\chi_i(j,s) = \vartheta\, q_i(j,s)^{\xi}\, y_i(j,s)^{1-\xi}\ , \tag{13}$$

where $\chi_i(j,s)$ is the output of export services produced with the employment of $q_i(j,s)$ units of firm's output, $y_i(j,s)$ units of homogeneous good, and $\vartheta \equiv \xi^{-\xi}(1-\xi)^{-(1-\xi)}$. Denoting with $c_i(j,s)$ the unit cost of the output and with p_{y_i} the price of the undifferentiated input, this corresponds to a unit cost per unit exported (the c.i.f./f.o.b. margin) equal to $b_{ih}\, c_i(j,s)^{\xi} p_{y_i}$, which exhibits a constant elasticity $\xi < 1$ with respect to $c_i(j,s)$. The limit case $\xi = 1$ is the iceberg costs case in which each unit of exported variety requires $1 + b_{ih}$ units of shipment of that variety. Empirical support for this representation of trade costs can be found in Hummels and Skiba (2004).[29]

The feature of this formulation that is crucial for our results is that there is an element of transportation costs which does not vary with the price of the good transported. This would also be true if, instead of combining goods with the undifferentiated input in (13), we combined them with differentiated labor inputs (be they of a low-s or high-s variety) as long as the composition of those differentiated labor input (and thus its composite price) does not vary with, s, the type of good being exported. The implication of this specification is that the effective share of variety-specific skill, s, in transportation costs is less than that in production $\xi\lambda \equiv \delta < \lambda$, which in turn implies that unit transportation costs are less than unit elastic to the f.o.b. price of the exported good.

Firm behavior

Firms maximize profits. The structure of preferences (11) is such that the price elasticity of demand faced by individual firms is constant and equal to $-\eta$, and therefore marginal revenue is proportional to the price charged by a constant factor $(\eta - 1)/\eta$. Profit maximization then implies a constant markup factor (price over marginal cost)

[29] Although they do not provide a micro-foundation of the export technology, the estimation approach they use to study the empirical relationship between price and transportation costs is directly consistent with (13). Their central estimate of the elasticity of the c.i.f./f.o.b. margin to price is $\xi = 0.6$.

equal to $(\eta - 1)/\eta$ in each destination market.

There are no restrictions to firm entry and exit, and no costs for entering or exiting. With multiple symmetric firms producing horizontally differentiated varieties for each good type, s, free entry and exit implies that, in equilibrium, all active firms exactly break even (total revenues equal total costs).

Equilibrium

An equilibrium for this economy consists of, for each skill/good type s, a measure of firms $N_i(s)$, a wage level $w_i(s)$, an allocation of output $q_i(j,s)$, inputs $(l_i(j,s), y_i(j,s))$, an allocation of consumption levels $x_{ih}(j,s)$, and prices $p_{ih}(s)$ for differentiated varieties in each origin-destination market pair $i \in M,\ h \in M$; and prices p_{y_i} for the undifferentiated good in each originating market, $i \in M$, such that:

(i) consumption $x_{ih}(j,s)$ maximizes the utility of consumers for every variety $j \in [0, N_i(s)]$ in every country $h \in M$;

(ii) prices $p_{ih}(s)$ maximize profits for every firm $j \in [0, N_i(s)]$;

(iii) total revenue equals total cost for every firm $j \in [0, N_i(s)]$ that is active in every country;

(iv) markets for the undifferentiated good clear in every country;

(v) product markets clear for every produced variety $j \in [0, N_i(s)]$;

(vi) labor markets clear;

for every skill variety $s \in S$ produced in every country $i \in M$.[30]

3.3 Autarky equilibrium

We first describe an equilibrium for this economy under conditions of autarky (omitting origin and destination market indicators). We take the undifferentiated input as the numeraire good and set its price equal to unity.

[30]We assume that the endowment of undifferentiated labor, Y_i, is large enough that production and consumption of the undifferentiated good in country i is always strictly positive in equilibrium.

Cost minimization given the technology (12) implies a marginal cost $w(s)^{\lambda}$ for a variety of good type s, and thus a price

$$p(s) = \frac{\eta}{\eta - 1}\, w(s)^{\lambda}. \tag{14}$$

Utility maximization yields a level of aggregate demand for the composite of differentiated goods equal to $Z = {P_Z}^{\zeta}$, where P_Z is the price of the composite; this in turn implies a level of demand for the good s composite equal to

$$X(s) = {P_Z}^{\zeta+\sigma} P(s)^{-\sigma}, \tag{15}$$

where $P(s)$ is the consumption based price index for goods of type s. Symmetry across the different varieties of a given good type, s, implies that the composite price for varieties of good type s is

$$P(s) = N(s)^{\frac{1}{1-\eta}} p(s). \tag{16}$$

This yields the following equilibrium level of demand for a variety of good s:

$$x(s) = X(s) \left(\frac{P(s)}{p(s)} \right)^{\eta} = {P_Z}^{\zeta+\sigma} N(s)^{\theta-1} p(s)^{-\sigma}, \tag{17}$$

where $\theta \equiv (\sigma - 1)/(\eta - 1) \in (0, 1)$.

Market clearing in product markets requires that the level of output, $q(s)$, of a firm producing a variety of good type s must equal demand, $x(s)$. Given the technology (12), the differentiated labor input demand of a firm producing varieties of good type s in equilibrium is

$$l(s) = \lambda\, w(s)^{\lambda-1} x(s) + \alpha\, w(s)^{\alpha-1} f. \tag{18}$$

Total revenue and cost for the firm are respectively

$$r(s) = \eta(\eta - 1)^{-1}\, w(s)^{\lambda} x(s), \tag{19}$$

$$c(s) = w(s)^{\lambda} x(s) + w(s)^{\alpha}. \tag{20}$$

The zero profit condition $r(s) = c(s)$ implied by free entry identifies an equilibrium level of output and demand for each firm equal to

$$x(s) = q(s) = (\eta - 1)\, f\, w(s)^{\alpha-\lambda}. \tag{21}$$

Substituting for the price from (14) in (17) and equating this with (21) identifies the equilibrium number of firms producing varieties of good type s:

$$N(s) = \left(\Omega\, {P_Z}^{\zeta+\sigma} w(s)^{-(\sigma-1)\lambda-\alpha}\right)^{\frac{1}{1-\theta}}, \tag{22}$$

where $\Omega \equiv \left(\eta^{\sigma}(\eta-1)^{1-\sigma} f\right)^{-1} > 0$ reflects patterns of substitution across products as well as the size of fixed costs.

Evaluating the equilibrium demand (17) at the price (14) and substituting it into (18) yields an equilibrium level of employment of differentiated labor for each firm:

$$l(s) = \left(\lambda(\eta-1)+\alpha\right) f\, w(s)^{\alpha-1}. \tag{23}$$

Finally, the labor market clearing condition $N(s)\, l(s) = L(s)$ identifies the wage:

$$w(s) = \left(\Omega\, {P_Z}^{\zeta+\sigma}\right)^{\frac{1}{\Theta}} \left(\frac{L(s)/f}{\lambda(\eta-1)+\alpha}\right)^{-\frac{1-\theta}{\Theta}}, \tag{24}$$

where $\Theta = (1-\lambda)(1-\theta) + \lambda\,(\sigma-\theta) + \alpha\,\theta > 0$.

Condition (24) delivers a full characterization of the relationship between skills scarcity, wages and prices:

Proposition 1 *If the varieties produced by different firms at the same price point – corresponding to the same skill variety – are closer substitutes than varieties across different price points – corresponding to different skill varieties ($\eta > \sigma$), then skill varieties that are comparatively scarcer are remunerated with higher wages and firms that employ them charge higher prices for their products.*

(Proofs of propositions are presented in the appendix.)

Note that, although we do not explicitly model quality neither with respect to labor inputs nor with respect to products, as discussed in Section 3.1 the model's representation of input based differentiation in the presence of comparative input is consistent with an interpretation where products are, at least in part, vertically differentiated.

Then, to the extent that quality upgrading requires using higher-quality inputs (e.g. "higher-skill" labor), it would amount in our model, to a firm in product segment, s', exiting that segment and entering another (higher-quality) segment, $s'' > s'$, a choice that would both be influenced by demand conditions (how much consumers are willing to pay for products in the higher-s segment) and by the supply of the inputs that are required to produce varieties in different segments.

Focusing on the relationship between fixed costs and wages also makes it possible to derive predictions about how firm size (revenue) varies with the wage and the price:

Proposition 2 *If fixed costs include differentiated labor costs ($\alpha > 0$), then revenue per firm, $r(s)$, is larger for firms employing comparatively scarcer skill varieties; otherwise revenue per firm is independent of s.*

Even in the case $\alpha = 0$, the equilibrium number of firms in a good type s, from (22), is decreasing with the price.[31] For $\alpha = 0$ a comparatively smaller number of firms producing higher-priced goods does not translate into those firms being larger, whereas for $\alpha > 0$ it does.

3.4 Equilibrium in a symmetric open economy

We next characterize an equilibrium for a symmetric open-economy case with m countries. The symmetry assumption implies that countries have the same endowments and share the same bilateral trade barriers: $L_i(s) = L(s)$ for every country $i \in M$ and every skill variety $s \in S$. As a consequence, the price indexes P_{Z_i}, $P_i(s)$, and the consumption composites, Z_i, $X_i(s)$, will be the same in every country, and so source and destination market indicators can be omitted. Symmetry also implies that prices for the undifferentiated input will be the same in all countries and can therefore all be normalized to unity. We use a "ˆ" to refer to values of variables in the open-economy case.

Cost minimization given the production technology (12) and the transportation technology (13) implies a marginal cost $\hat{w}(s)^{\lambda}$ for a variety of good s produced in a country and sold in the domestic market and a corresponding marginal cost if the same

[31]For $\alpha = 0$ condition (22) implies that the number of firm is proportional to $w(s)L(s)$. Evaluating (24) for $\alpha = 0$, we see that $\sigma > 1$ is a sufficient condition for $w(s)L(s)$ (and thus $N(s)$) to be increasing in $L(s)$.

variety is exported to a foreign market equal to

$$\hat{w}(s)^{\lambda} + b\,\hat{w}(s)^{\delta} = \tau(s)\,\hat{w}(s)^{\lambda}, \qquad \tau(s) \equiv 1 + b\,\hat{w}(s)^{\delta-\lambda}, \tag{25}$$

where $\tau(s)$ represents the ratio of the marginal cost of exports relative to that of a domestically sold goods. Note that since the labor intensity of export services is lower than that of goods production ($\delta < \lambda$), this ratio is lower the higher $\hat{w}(s)$.

In every country, consumers demand both domestic and imported varieties of the differentiated good. As in the autarky case, profit-maximizing prices feature a constant markup over marginal cost and so the price of imported varieties is $\tau(s)$ times the price of domestic varieties. The price of the composite of product varieties of type s is then

$$\hat{P}(s) = \Big(1 + (m-1)\,\tau(s)^{1-\eta}\Big)^{\frac{1}{1-\eta}}\,\hat{N}(s)^{\frac{1}{1-\eta}}\,\hat{p}(s)\,. \tag{26}$$

Proceeding as we did to derive (17), we can obtain expression for the level of demand originating in the domestic market and that originating in the $m-1$ export markets, which are respectively equal to

$$\begin{aligned} \hat{x}(s) &= \hat{P}_Z{}^{\zeta+\sigma}\Big(1 + (m-1)\,\tau(s)^{1-\eta}\Big)^{\theta-1}\,\hat{N}(s)^{\theta-1}\,\hat{p}(s)^{-\sigma}, \\ \hat{x}^*(s) &= (m-1)\,\tau(s)^{-\eta}\,\hat{x}(s). \end{aligned} \tag{27}$$

The production of any given firm has to satisfy domestic demand $x(s)$, foreign demand $x^*(s)$, and the units of output employed in the production of export services, according to the technology (13). For each unit of exported variety the firm must produce b units of export services at a marginal cost $\hat{w}(s)^{\delta}$. This requires $\xi\,b\,\hat{w}(s)^{\delta-\lambda} = \xi\,(\tau(s)-1)$ units of output, each at a marginal cost $\hat{w}(s)^{\lambda}$, and $(1-\xi)\,b\,\hat{w}(s)^{\delta}$ units of the undifferentiated good. Market clearing for products thus requires

$$\hat{q}(s) = \hat{x}(s) + \Big(1 + \xi\,\big(\tau(s)-1\big)\Big)\,\hat{x}^*(s). \tag{28}$$

Labor demand includes employment in the production of $\hat{q}(s)$ units of output and that required to produce $b\,\hat{x}^*(s)$ units of export services, in addition to that which comes from fixed costs:

$$\hat{l}(s) = \lambda\,\hat{w}(s)^{\lambda-1}\hat{q}(s) + \alpha\,w(s)^{\alpha-1}f. \tag{29}$$

Total revenue and total cost are respectively

$$\hat{r}(s) = \eta(\eta-1)^{-1}\,\hat{w}(s)^{\lambda}\left(1+(m-1)\,\tau(s)^{1-\eta}\right)\hat{x}(s), \tag{30}$$

$$\hat{c}(s) = \hat{w}(s)^{\lambda}\left(1+(m-1)\,\tau(s)^{1-\eta}\right)\hat{x}(s) + \hat{w}(s)^{\alpha} f. \tag{31}$$

The equilibrium level of $\hat{x}(s)$ for which firms break even is

$$\hat{x}(s) = \frac{(\eta-1)\,f\,\hat{w}(s)^{\alpha-\lambda}}{1+(m-1)\,\tau(s)^{1-\eta}}. \tag{32}$$

The presence of a trade cost wedge, $\tau(s)$, that is decreasing in the wage strengthens the inverse relationship between quantity and price that we have already discussed in the autarky equilibrium for $\alpha < \lambda$.

The system of (27) and (32) yields the number of firms producing varieties of a given good type, s:

$$\hat{N}(s) = \left(\Omega\,\hat{P}_Z^{\;\zeta+\sigma}\left(1+(m-1)\,\tau(s)^{1-\eta}\right)^{\theta}\hat{w}(s)^{-(\sigma-1)\lambda-\alpha}\right)^{\frac{1}{1-\theta}}, \tag{33}$$

where we have substituted for the price in the domestic market, $\hat{p}(s) = \left(\eta/(\eta-1)\right)\hat{w}(s)^{\lambda}$. The measure of firms operating with a given skill is a decreasing function of the wage.[32]

Substituting (32) into (29) gives

$$\hat{l}(s) = \left(\left(\xi+(1-\xi)\,\mu(s)\right)\lambda(\eta-1)+\alpha\right) f\,\hat{w}(s)^{\alpha-1}, \tag{34}$$

where

$$\mu(s) = \frac{1+(m-1)\,\tau(s)^{-\eta}}{1+(m-1)\tau(s)^{1-\eta}} = \frac{\hat{p}(s)}{\bar{p}(s)} < 1 \tag{35}$$

is the ratio of the price charged in the domestic market over the average price charged across all markets served by the firm (weighted by demand shares). It can be shown that $\mu(s)$ is an increasing function of the wage.[33]

[32]This can be shown by substituting $\hat{w}(s)^{-((\sigma-1)\,\lambda)} = \hat{w}(s)^{\frac{\sigma-1}{\eta-1}\lambda(1-\eta)} = \hat{w}(s)^{\theta\,\lambda\,(1-\eta)}$ into (33).

[33]This statement holds under fairly mild conditions; the details are discussed in the appendix.

The labor market clearing condition $\hat{N}(s)\,\hat{l}(s) = L(s)$ gives

$$\hat{w}(s) = \left(\Omega\,\hat{P}_Z^{\;\zeta+\sigma}\right)^{\frac{1}{\Theta}} \left(1 + (m-1)\,\tau(s)^{1-\eta}\right)^{\frac{\theta}{\Theta}} \left(\frac{L(s)/f}{(\xi + (1-\xi)\,\mu(s))\lambda(\eta-1) + \alpha}\right)^{-\frac{1-\theta}{\Theta}}. \tag{36}$$

To study the relationship between a firm's revenues from domestic sales, $\hat{r}(s)$, and its export revenues, $\hat{r}^*(s) = (m-1)\,\tau(s)^{1-\eta}\,\hat{r}(s)$, we can focus on the firm's export intensity, as measured by the ratio of export revenues to domestic revenues,

$$\rho(s) \equiv \frac{\hat{r}^*(s)}{\hat{r}(s)} = (m-1)\,\tau(s)^{1-\eta}. \tag{37}$$

We are then in a position to arrive at a prediction concerning the relationship between scarcity of a skill variety, its wage, the export intensity of firms and their size:

Proposition 3 *In a symmetric open-economy equilibrium where mean trade-adjusted prices increase less than proportionally with domestic prices:*

(i) skills that are comparatively scarcer are remunerated with higher wages, and firms that pay comparatively higher wages earn a greater proportion of their revenues in export markets;

(ii) if fixed costs include labor costs ($\alpha > 0$), then those firms that earn a greater proportion of their revenues in export markets and pay higher wages are comparatively larger firms; otherwise export intensity is independent of firm size.

Propositions 1 to 3 predict the positive correlation between price, wage and export intensity that we have documented in Section 2. A positive correlation with firm size may also be present but is not necessary for the other correlations to emerge. This framework can thus generate predictions on the relationship between firm size and export performance that are not derived from exogenous idiosyncratic sources of heterogeneity. Instead, the model explains firm heterogeneity as resulting from the comparative scarcity of the types of skills that firms employ. This channel alone is sufficient to generate a positive correlation between wages and output prices. Non-price-proportional transportation costs are a necessary ingredient for this correlation to translate into a positive correlation between wages and export intensity.

In equilibrium, workers endowed with different skill varieties earn different wages and they are employed by firms which charge different prices. Through this channel, the heterogeneity in the export success of firms predicted by Proposition 3 translates into differential effects of market integration on the wages of different workers, and so market integration affects the distribution of wages: in comparison with autarky, market integration raises the demand for comparatively scarcer worker types relative to that of comparatively less scarce worker types. This insight is formalized by the following result:

Proposition 4 *In a symmetric economy, for each skill variety, s, the ratio, $\hat{w}(s)/w(s)$, of the wage under market integration to the wage under autarky is larger the scarcer is the skill variety.*

This result amounts to a prediction of *ratio dominance* of the wage distribution under market integration relative to that under autarky.[34] Ratio dominance implies Lorenz dominance, i.e. a higher Gini index for the new (open-economy) distribution relative to the initial (autarky) distribution. It also implies Lorenz dominance for comparisons made over any given truncation of the original distribution, i.e. an increase in the Gini coefficient for any percentile sub-range of the original distribution. Thus, under fairly general conditions, the model predicts that international market integration raises concentration in the wage distribution.

3.5 Further predictions, generalizations and extensions

The theoretical framework we have described can also readily accommodate exogenous idiosyncratic technology differentials, which adjust marginal cost by a firm-specific level of total factor productivity. If the firms producing varieties of a given good type, s, also differ in terms of their productivity the wage will still be the same across workers endowed with the same skill variety but heterogeneity in productivity will

[34]Adapting Preston (2006)'s definition, we say that a discrete distribution f_1 of a variable, w, for J individuals indexed by $j = 1, \ldots, J$, ratio dominates distribution f_0 of the same variable if and only if

$$\ln w_1^{j+1} - \ln w_0^{j+1} > \ln w_1^{j} - \ln w_0^{j}, \qquad \forall j \in \{1, \ldots, J-1\}. \tag{38}$$

In other words, when individuals are ordered in terms of (increasing) wages, the new distribution shows a greater proportional increase in the income of the $(j+1)$th individual compared to that of the jth individual, for any j.

translate into heterogeneity in prices, revenues and profits across firms producing varieties that use the same skill variety, s. If the distribution of firms' productivity types is independent of s, this will weaken the observed relationship between input prices and output prices; nevertheless, for any given productivity type, the relationship between price, wages and export intensity will be as we have described in our analysis.[35] On the other hand, if there is some mechanism that results in a systematic positive sorting of firm productivity types to good types, s; then higher priced-goods will be produced and sold by more productive firms who pay higher wages to their workers.

In both cases, our modeling framework is capable to predictions about how the distribution of measured firm productivity – which is implicitly modeled as being "factor embedded" – responds to trade, even in the absence of firm exit. Unlike in models where firm heterogeneity only comes from factor-neutral productivity differentials, in this model trade affects the distribution of measured firm productivity also through the intensive margin, not just through the selection of active firms.

Also, our theoretical arguments have been developed for a setup with a single category of labor inputs. In practice production combines workers with different occupations each carrying out different tasks. With multiple categories of workers, the simple one-to-one mapping between input types and output types that applies to the single-input case needs be extended to allow for output differentiation to result from different combinations of input types within categories. The quasilinear specification of preferences formalized in (9) can also be generalized to include multiple categories of differentiated goods.

Finally, although the main motivation behind our modeling exercise is to explain variation on the intensive margin of exports, the model can be augmented with features that parallel those of (as in Melitz, 2003) to produce predictions about selection of firms into export markets. If firms must incur a fixed cost, f_X, for exporting, then, as potential export revenues are increasing with s, and since gross profits are proportional to revenues, there will be a cutoff level, $\tilde{s}$, lying between $\underline{s}$ and $\overline{s}$ above which firms will choose to export and below they will choose not to do so (as long as f_X lies between the respective levels of potential profits of firms producing $\underline{s}$ and $\overline{s}$-type varieties). If fixed costs do not involve the differentiated input ($\alpha = 0$), the variation in export revenues is

[35] A hybrid formulation of this type could be used to obtain structural estimates of the implied contribution of input based differentiation to output price variation.

unrelated to a firm's total revenues, and so selection into export markets is unrelated to firm size; but if fixed costs involve the differentiated input ($\alpha > 0$), firms with higher export revenues are also larger firms, and so selection into exporting becomes positively related to size.

4 Summary and conclusion

We have presented a theory of international trade where goods are modeled as being horizontally differentiated on the basis of the inputs that are required to produce them – as well as because different firms produce them. As is customary in the literature on international trade in differentiated products, starting with Krugman (1979), the model assumes a monopolistically competitive market structure, with the only (but important) difference that trade costs are not of the iceberg type but fall with price in relative terms.

In the model, the relative scarcity of different skill varieties determines the wage firms pay to employ workers with a given skill variety as well as the price of the goods that are produced using that skill variety. The combination of non-iceberg transport technologies, input based product differentiation and comparative skills scarcity is then sufficient to predict a positive correlation between wages, prices and share of foreign sales on total sales, as we observe it in the data. The model also predicts market integration to produce a systematic increase in relative wage differentials.

Theoretical trade models that derive all effects from factor-neutral productivity differentials struggle to rationalize these patterns in a unifying framework, even when accounting for imperfections in the labor market or quality upgrading. These models leave out a channel that is both in evidence in the data and in line with standard general-equilibrium thinking: firm are inevitably supply-constrained with respect to the characteristics of their labor force. One would expect that a factor-neutral productivity advantage should help mitigate and possibly overcome such constraints. However, if that were the case, then the extent of the correlation that we observe between prices, wages and export performance should be similar across different labor types; but this is not what we see.

Evidence from French exporter data lends support to our model's interpretation of the relationship between prices, wages and export performance on the intensive margin: wages, prices, and export intensity are positively correlated and co-move in response to variation in labor market conditions that is exogenous to firms' decisions. Three key facts emerge, which are in line with the mechanisms we model. First, only a subset of worker types seem to matter for the price that the firm charges. Second, the sorting of worker types by wage level or occupational category are unable to explain the different extent to which different worker types matter for the price that the firm charges. Third, the extent of price-to-wage correlation for individual worker types is well predicted by the extent of price-to-wage correlation based only on the component of wage variation that comes from variation in labor market conditions. Accounting for these facts requires a change of focus from factor-neutral productivity differentials to input based differentiation.

The model we describe remains tractable enough to accommodate further extensions. We have already noted how the model can be readily re-interpreted to account for product quality and extended to allow for firm heterogeneity in total factor productivity and incorporate fixed exporting costs. Such extensions would of course produce a richer set of predictions, but all the results of the baseline version of the model remain true, conditional on a given level of total factor productivity. Input based differentiation should therefore be thought of as a complementary mechanism that can work alongside factor-neutral productivity differentials, rather than as a competing paradigm.

The role played by labor market supply in the exporting decisions of firms, which is the focus of the present paper, not only appears to be of first-order prominence in the evidence that we have quoted and documented, but also points to distinctive policy implications. With input based differentiation, trade liberalization produces effects on the distribution of wages, even in the absence of a trade-induced selection of firms (in either the domestic or the export market) and independently of the usual discriminating categories (such as firms that are ex-ante defined as low- or high-productivity firms, and workers that are ex-ante grouped as low- or high-skill), and these effects are linked to the composition of domestic labor market supply. This angle has been overlooked by the literature, and opens new possibilities for understanding the interplay between trade policies and labor market outcomes.

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Appendix

A Data sources

This section builds on Harrigan et al. (2016) and Sly et al. (2016). We are grateful to Gianluca Orefice and Farid Toubal for their help.

A.1 Workers

The annual declaration of social data (DADS) is an administrative dataset that collects mandatory information from declarations that all businesses with employees must make to the French authorities. The declarations concern all firms located within the French territory, excluding governmental entities and self-employed individuals.

We use the version "*Postes*" of the DADS dataset, in which a record is a contract employer-employee in a year. The advantage of this version of the dataset is that it covers the universe of employer-employee contracts for France. A disadvantage is that the employee identifier "*Ident–s*" is unique within the same year, but not across years; therefore we can only exploit cross-sectional information for the employees, not longitudinal information. Along the employer dimension a panel analysis is possible, since the firm identifier "*Siren*" is unique across years. We observe the following information for each employer-employee match:

- *Employer*: firm identifier (*Siren*), plant identifier (*Nic*), region, province and municipality of location (respectively *Regt*, *Dept*, *Comt*), four-digit NAF code (consistent with the NACE Rev. 2) of the firm (*Apen*), legal category of the firm (*Catégorie_ juridique*).
- *Employee*: employee identifier (*Ident–s*), gender (*Sexe*), year of birth (constructed from *Age*), region, province and municipality of residence (respectively *Regr*, *Depr*, *Comr*).
- *Contract*: type of employee (*Typ_emploi* classified along the dimensions: regular, apprentice, other), type of duration (*Cpfd* classified along the dimensions: full time, part time, other), type of relationship (*Contrat_travail* classified along the dimensions: indeterminate, determinate, apprenticeship, other). Combinations of these three categorical variables define a contract type.
- *Occupation*: category of occupation according to the classification *Professions et Catégories Socioprofessionnelles* (PCS), which distinguishes non-agricultural workers into five broad categories: (2) *Artisans et chefs de l'entreprise*, (3) *Cadres et professions intellectuelles supérieures*, (4) *Professions Intermédiaires*, (5) *Employés*, and (6) *Ouvriers*; each group is in turn subdivided into finer categories, up to four digits, which yields a detail of 465 categories.[36]
- *Compensation*: gross wage in a year (*S–brut*), hours worked in a year (*Nbheur*).

[36]Further information can be found at https://www.insee.fr/fr/information/2400059.

Data cleaning

We exclude from the sample contracts with firms that are not private legal entities (*Catégorie_juridique* = 4, 7, 9) and contracts with firms whose main activity is not in manufacturing; thus we keep firms with *Apen* codes between (and including) Section 10, "*Industries alimentaires*", and Section 32, "*Autres industries manufacturières*", of the NACE classification.[37] We drop records of contracts for which there is no information on wage and number of hours. We drop records of contracts for which there is a strictly positive wage, but the number of hours in a year is less than 35 (which is a working week in France). We also drop records of contracts for which there is a strictly positive number of hours but in which the wage in a year is less than €8×35, which is about a week's work at the French minimum wage.

Aggregation

A record in the dataset is an employer-employee contract at the plant level in a year. For all contracts involving the same employee (*Ident-s*) with the same contract characteristics (as discussed in the next paragraph), same occupation, within the same plant, of the same firm in the same year, we sum hours and gross wage in the year. The same employee might have a contract with the same characteristics and the same occupation with the same firm in a given year, but in different plants. In that case we add up hours and wages and assign the total amounts to the firm plant in which the employee receives the highest yearly compensation. The same employee located in the same plant of the same firm might have more contracts with different characteristics and/or different occupations (*PCS*) in the same year. In such cases we add up hours and wages and assign their total amount to the pair of contract and occupation types in which the employee receives the highest yearly compensation from the firm. Finally, note that a person might be employed by two different employers in the same year. In such cases we select the location of residence where the worker receives the highest yearly compensation.

Worker types

We aggregate contract characteristics across several dimensions. *Contract_characteristics*: out of the thirty-six possible combinations of contract types, we censor those which occur with a frequency lower than 0.1%. This yields nineteen contract groups (*Gc*), one residual class and eighteen determined types. *Demographic characteristics*: we classify the year of birth of an employee into five ranges: (i) $\leq$ 1955; (ii) > 1955 and $\leq$ 1965; (iii) > 1965 and $\leq$ 1975; (iv) > 1975 and $\leq$ 1985; (v) > 1985 and $\leq$ 1995; and then we group each age range with gender. This yields ten groups of demographic characteristics (*Gd*). *Location_characteristics*: for each contract we keep track of the province of residence of the employee and the province in which the working place of the contract is located. This yields 9,501 groups of location characteristics (*Gl*). The intersection of *Gc-Gd-Gl* yields a grid of 97,216 *Narrow_characteristics_cells*. The intersection of *Gc-Gd* yields a grid of 183 *Broad_characteristics_cells*. A worker type is the intersection of a cell (detailed or broad) with an occupation. We observe 408 *Detailed_occupations* (PCS at four digits) grouped into twenty-eight *Broad_occupations* (PCS at 2 digits). The intersection of the two dimensions yields respectively 1.2 millions of *Detailed_worker_types*, and 3,448 *Broad_worker_types*.

[37]Further information can be found at https://www.insee.fr/fr/information/2406147.

A.2 Customs

We use records of individual export and import transactions of goods at the level of product-country destination or origin-firm-year for the period 2010-2013, collected by the French customs. For each record we know the value (in Euro) and the weight (in Kilograms). Product categories are classified according to the Combined Nomenclature at 8 digits (NC8). The data covers the trade transactions of firms at the French Customs and all foreign countries.[38]

Data cleaning

We drop transactions with a value that is less than €1,000. As we combine the information on a firm's export transaction with information on the firm's employees and revenues, which cannot be detailed at the product level, we focus on those export transactions that are most representative of the overall output of the firm. For this purpose, we exclude from the analysis the export of products that are in a different segment than the main segment at the firm by volume of sales. We compute the value of exports of each firm within a year by sections of Combined Nomenclature at 6 digits (NC6) and keep the export transactions of those NC8 products that belong to the section NC6 with the highest value of exports for the firm in a year. To make it possible to compare firms within a meaningful group of similar competitors, we restrict the sample to the cells of NC8 product-destination-year for which we observe at least ten distinct French exporter firms.

Prices

For each NC8 product-destination-firm-year transaction record, we compute the unit value (€ per kilogram) which we consider a proxy for the export price, at the product-destination-firm-year level. We compute the average export price across all firms in the same NC8 product-destination-year cell. The ratio of the firm price to the average price yields the *relative* price that a firm charges at the level of a NC8 product-destination-year, for all the products exported by the firm within the section NC6 with the highest value of export for the firm in a year. An analysis of the variance of prices at the level of NC8 product-destination-firm- year shows that 12.3% of the variation of price is due to the interaction of product, destination and year characteristics, but the same characteristics explain virtually a null share of the variance of the relative price. We conclude that the relative price provides an effective normalization for product, destination and year variation that isolates the variation of prices across firms.

[38]Note that this also includes firms with an import-export business model, without employees in France; we will exclude this portion form the analysis when merging the trade transactions with the DADS dataset. Moreover, it should be noted that there are firms recorded at the customs and with employees in France but that do not pay taxes in France (such as wholesale traders). These firms will then be present in the custom data and in the DADS, but not in the dataset of balance sheets and income statement of firms, the Ficus–FARE dataset which will be our third source of information.

Aggregation

We conduct our analysis at the firm level, and we keep track of two types of prices that are representative at the firm level, the "*Main_price*" and the "*Main_relative_price*", which are respectively the price and the relative price of the NC8 product-destination pair with the highest value of export for the firm in the year. Second, we compute a weighted average price and a weighted relative price across products within a firm in a year; where the weights are the shares of the NC8 products in the total value of export of the firm in the year. This yields an *Average_price* and an *Average_relative_price* for each firm in a year; where the latter is representative of the price charged by a firm compared with the other firms serving the same destination, in the same year.

When we compute the price-to-wage correlation reported in the figures, we use the *Main_relative_price*; the analysis does not change qualitatively in any significant way when we use the *Average_relative_price*.

A.3 Firms

Data on firms' characteristics comes from the Ficus-FARE dataset, which contains exhaustive information on the balance sheets of firms paying taxes in France. The information contained in the Ficus-FARE dataset is collected for fiscal purposes. Firms which do not pay taxes in France (such as wholesale traders) do not have to report a tax declaration therefore they are unlikely to show up in the Ficus–FARE dataset. However, these firms might have employees in France and indeed they are obliged by law to report the information included in the DADS.

The variables of the Ficus–FARE dataset that we use in our analysis are "*Ciffres d'affaires nets en France*" (*redi-r420*), which measures revenue on the domestic market, and "*Total exportations*" (*redi-r410*) as revenue on the export markets. The ratio of revenue abroad over revenue on the domestic market is the measure of *Export intensity* consistent with the definition we use in our theoretical discussion. Levels of exports reported in the Ficus-FARE may be viewed as being less reliable than corresponding information in the customs data: the first source consists of self-reported information, while the latter is recorded by the customs authorities. Therefore, whenever it is possible, we consider as a firm's total foreign revenue the total value of exports by the firm in a given year as reported by the customs.

We restrict our analysis to firms in the manufacturing sector with employees in France. Therefore, we exclude from the analysis the information on revenue and export transactions of firms which are not included in the consolidated dataset based on the DADS.

B Proofs of propositions

Proof of Proposition 1

The derivation of (22) and (24) is discussed in the text. From (24) notice that $(1-\theta)/\Theta \geq 0$ if and only if $\theta \leq 1-\lambda+\lambda\,\sigma$; and since $\sigma > 1$, then $1-\lambda+\lambda\,\sigma > 1$. The condition $\eta > \sigma$ is a necessary and sufficient condition for $0 < \theta < 1$ for every $\sigma > 1$. Therefore, the wage equation (24) implies that the wage is higher for scarcer skills. Price (14) is increasing in $w(s)$. □

Proof of Proposition 2

The equilibrium level of revenue $r(s)$ is obtained by substituting the equilibrium demand (21) in the expression for the revenue (19). Then the elasticity of revenue to wage is given by

$$\frac{dr(s)}{dw(s)}\frac{w(s)}{r(s)} = \alpha \geq 0.$$

□

Proof of Proposition 3

A necessary and sufficient condition for for $\mu(s)$ to be increasing in the wage and the price in equilibrium (and thus for unit trade costs to be increasing less than proportionally with price) is

$$\eta \leq \frac{\tau(s)}{\tau(s)-1} + \frac{(m-1)\,\tau(s)^{1-\eta}}{\tau(s)-1}.$$

A sufficient, although not necessary, condition is

$$\eta \leq \frac{\tau(s)}{\tau(s)-1},$$

where the ratio $\tau(s)/(\tau(s)-1)$ is a decreasing function of $\tau(s) = 1 + b\,w(s)^{\xi\,\lambda}$. Therefore, if the sufficient condition is satisfied when $\tau(s)$ is at its maximum, i.e. at the lowest wage level, $\underline{w}$, it has to hold for all wage levels. Then,

$$b \leq \frac{\underline{w}^{\xi\,\lambda}}{\eta - 1} \tag{39}$$

is a sufficient condition for $\mu(s)$ to be increasing in $w(s)$; i.e. trade costs cannot be "too large".

Substituting for $\mu(s)$, from (35), in the wage equation (36), the wage in open economy can be expressed as

$$\hat{w}(s)\,h\big(\hat{w}(s)\big) = \kappa\big(\hat{w}(s)\big)\left(\Omega\,\hat{P}_Z^{\;\zeta+\sigma}\right)^{\frac{1}{\Theta}}\left(\frac{L(s)/f}{\lambda\,(\eta-1)+\alpha}\right)^{-\frac{1-\theta}{\Theta}},$$

where the two functions $\kappa\big(\hat{w}(s)\big)$ and $h\big(\hat{w}(s)\big)$ are both strictly positive and are given by

$$\kappa\big(\hat{w}(s)\big) = \Big(1 + (m-1)\,\tau(s)^{1-\eta} - (1-\xi)\,\beta\,(m-1)\,\Big(\tau(s)^{1-\eta} - \tau(s)^{-\eta}\Big)\Big)^{\frac{1-\theta}{\Theta}},$$
$$h\big(\hat{w}(s)\big) = \Big(1 + (m-1)\,\tau(s)^{1-\eta}\Big)^{\frac{1-2\theta}{\Theta}},$$

where $\beta \equiv \lambda(\eta-1)/\big(\lambda\,(\eta-1)+\alpha\big) \in (0,1]$. Note that $\tau(s)$ is a decreasing and convex function of the wage. This is sufficient to conclude that both $\kappa\big(\hat{w}(s)\big)$ and $h\big(\hat{w}(s)\big)$ are increasing and concave functions of the wage, for every $\eta > 1$.

Since $\sigma > 1 \Longleftrightarrow 1-\theta < \Theta$, the power $(1-\theta)/\Theta \in (0,1)$ of an increasing concave function is a concave function. Therefore the function $\kappa\big(\hat{w}(s)\big)$, which disciplines the right hand side of the wage equation, is an increasing and concave function of the wage, with a strictly positive intercept. The left-hand side of the wage equation $\hat{w}(s)\,h\big(\hat{w}(s)\big)$ stems from the origin; but there are two cases which should be discussed:

(i) For $1-2\theta \geq 0$, the function $h\big(\hat{w}(s)\big)$ is increasing in the wage and the product $\hat{w}(s)\,h\big(\hat{w}(s)\big)$ is increasing and convex in the wage.

(ii) For $1-2\theta < 0$, the function $h\big(\hat{w}(s)\big)$ is decreasing in the wage. However, the absolute value of its elasticity is lower than $\big((2\theta-1)/\Theta\big)\big(\lambda(\eta-1)(\tau(s)-1)/\tau(s)\big)$; where it should be noted that $\big(d\tau(s)/d\hat{w}(s)\big)/\big(\hat{w}(s)/\tau(s)\big) > -\lambda(\tau(s)-1)/\tau(s)$ for every $\tau(s) > 1$. Imposing the restriction $\eta \leq (\tau(s)-1)/\tau(s)$, as obtained in our previous discussion of $\mu(s)$, the elasticity of $h\big(\hat{w}(s)\big)$ is negative but less than unity in absolute value. The left-hand side of the wage equation $\hat{w}(s)\,h\big(\hat{w}(s)\big)$ is an increasing and concave function of $w(s)$.

In both cases there exists one and only one intersection with the right hand side of the wage equation disciplined by the strictly positive, increasing and concave function $\kappa\big(\hat{w}(s)\big)$. A lower endowment $L(s)$ shifts the right hand side of the wage equation upward, and the intersection occurs at higher wage level, implying that $\hat{w}(s)$ is increasing in s. In turn this means that $\underline{w}$ in (39) becomes $\hat{w}(\underline{s})$.

The second part of the Proposition 3 follows from the fact that $\hat{w}(s)$ is increasing in s together with the definitions of $\rho(s)$, which a decreasing function of $\tau(s)$ (which in turn is a decreasing function of $\hat{w}(s)$). The properties stated in Proposition 2 for the autarky case also apply to the open economy case. Hence, for $\alpha > 0$, an increasing $\rho(s)$ also implies a positive relationship between firm size (in terms of revenue) and export intensity. □

Proof of Proposition 4

Substituting for $\kappa\,(\hat{w}(s))$ and $h\,(\hat{w}(s))$, from the proof of Proposition 3, in the expression of the ratio $\hat{w}(s)/w(s)$ yields:

$$\begin{aligned} \frac{\hat{w}(s)}{w(s)} &= \left(\frac{\hat{P}_Z}{P_Z}\right)^{\frac{\zeta+\sigma}{\Theta}} \left(\frac{\Big(1+\nu\big(\tau(s)\big)\Big)^{1-\theta}}{\Big(1+(m-1)\,\tau(s)^{1-\eta}\Big)^{1-2\theta}}\right)^{\frac{1}{\Theta}} \\ &\geq \left(\frac{\hat{P}_Z}{P_Z}\right)^{\frac{\zeta+\sigma}{\Theta}} \Big(1+(m-1)\,\tau(s)^{1-\eta}\Big)^{\frac{2\theta-1}{\Theta}}, \end{aligned}$$

where $\nu\big(\tau(s)\big) = (m-1)\,\tau(s)^{1-\eta}\left(1-(1-\xi)\big(1-\tau(s)^{-1}\big)\dfrac{\lambda(\eta-1)}{\lambda(\eta-1)+\alpha}\right)$ is a positive value not greater than $(m-1)\,\tau(s)^{1-\eta}$ and decreasing in $\tau(s)$. Since $\eta > 1$ and $\theta \in (0,1)$, and since $\tau(s)$ is decreasing in the wage, $\mu(s)$ being increasing in the wage is a sufficient condition for the ratio $\hat{w}(s)/w(s)$ to be non-decreasing in s.

□

C Average exporter wage premia

Table 3 documents exporter wage premia, both at the extensive and at the intensive margin.

French exporters pay wages that are on average 4.8% higher than those of non-exporters, a figure that is in line with findings for other countries (e.g., Norway Irarrazabal et al., 2013). However, we also see a strong positive correlation between wages and export conduct on the intensive margin: export wage premia vary substantially with export intensity – measured as the ratio of export revenues to domestic revenues – ranging from 1% for exporters in the bottom quintile of the distribution of export intensity, to 6% for those in the top quintile; all differences across quintiles being statistically significant.

Table 3: Exporter wage premia

ln *Hourly Wage*	*Export Status*	*ln Export Intensity*
Export Status	0.048***	
	(0.003)	
ln Export Intensity		
1st Quintile		0.010***
		(0.004)
2nd Quintile		0.015***
		(0.005)
3rd Quintile		0.024***
		(0.005)
4th Quintile		0.038***
		(0.005)
5th Quintile		0.059***
		(0.006)
No. Clusters (sector-year-province)	39,301	39,301
R^2	0.891	0.891
No. Obs.	2,467,937	2,467,937

NOTE: Pooled OLS regression of the log wage against exporter status dummy, and, for exporting firms only, an indicator for the quintile in the distribution of export intensity that the exporter belongs to (within NACE 4-digit sector-year categories). All specifications include year dummies and sector-worker type dummies. Significance: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the sector-year-province level and are reported in parentheses.

D Additional evidence (not for publication)

In this section we provide additional evidence which complements that already discussed in the paper. The data are described in Appendix A. The notation is consistent with that used in the rest of the paper.

D.1 Evidence on price-to-wage correlation by worker type

Figure 2 plots mean (log) wages against the Spearman's rank correlation index between export prices (proxied by unit values, as detailed in Section A of the appendix) and wages; within a labor market segment, where each dot is a different labor market segment. We find a positive and statistically significant correlation between prices and wages only for the labor market of few worker types; for the vast majority of worker types there is no significant correlation, and there is no evidence that the correlation is stronger at higher wages.

When we look at the occupational categories and sector pairs of those worker types that exhibit the highest or the lowest levels of price-to-wage correlation we cannot see any clear pattern (Table 4).

D.2 Evidence on export-to-wage correlation by worker type

The export wage premium that emerges on average hides considerable variation across labor market segments. Employer-employee matches that belong to a given labor market segment refer to firms that hire the same worker type, supply goods that belong to the same sector HS4, produce in the same region, in the same year. Conditional on these dimensions, we observe variation across firms in wages, prices and export intensity. Figure 3 plots mean (log) wages against the Spearman's rank correlation index between export intensity and wages within a labor market segment; each dot is a different labor market segment.

Not only is there wide dispersion in the correlation between wages and export intensity, with the correlation index being statistically significant only in a small subset of cases (roughly 12%); but we can also not discern any systematic relationship between the magnitude of the export intensity-to-wage correlation and the mean wage.

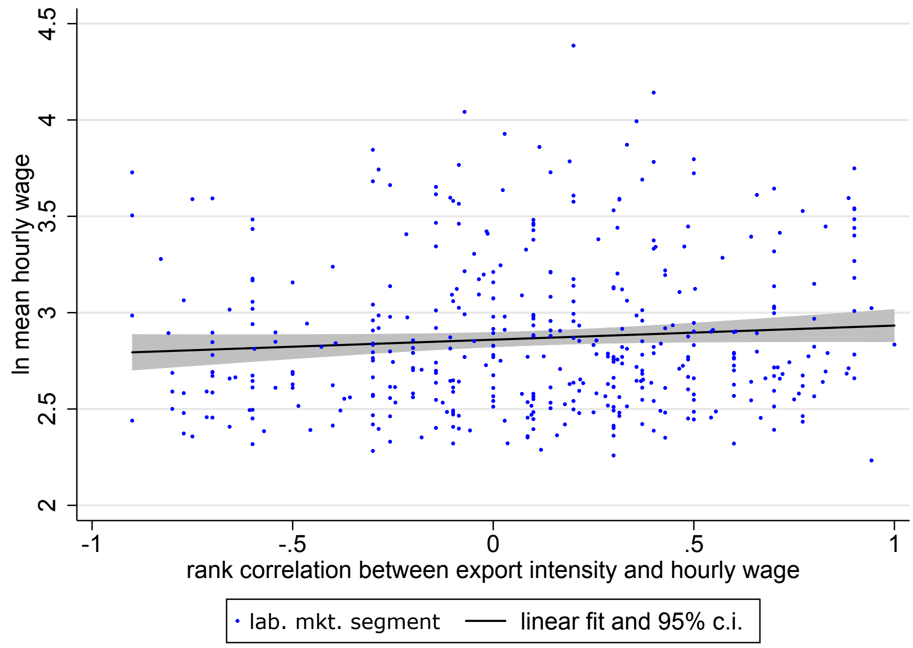
Figure 2: Mean wage against correlation of export prices and wages

NOTE: Each point refers to a labor market segment, that is the 4-dimension cell (worker type×sector HS4×region×year). A worker type is defined in terms of occupational category, contract type, geographic and demographic characteristics.

Table 4: Top five and bottom five sector×occupation pairs by price-to-wage correlation, average 2010-2013

Sector	*2-digit occupation*	*Price-to-wage correlation*	*p-value*
TOP FIVE (FROM HIGHEST TO LOWEST)			
Plastic manufacturing	Qualified operator	0.721	0.018
Processed meat	Administrative employee	0.697	0.025
Processed meat	Unskilled production worker	0.679	0.039
Machines	Accounting manager	0.624	0.053
Wine	Production manager	0.582	0.060
BOTTOM FIVE (FROM HIGHEST TO LOWEST)			
Cosmetics	Accounting manager	−0.415	0.214
Machines	Qualified operator	−0.516	0.071
Lenses	Production technician	−0.539	0.108
Cosmetics	Administrative employee	−0.564	0.089
Plastic manufacturing	Production technician	−0.588	0.074

Figure 3: Mean wage against export intensity-to-wage correlation



NOTE: Each point refers to a labor market segment, that is the 4-dimension cell (worker type×sector HS4×region×year). A worker type is defined in terms of occupational category, contract type, geographic and demographic characteristics.